AV 10/523,139

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 127 774 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
29.08.2001 Bulletin 2001/35

(51) Int Cl.7: **B62D 5/04**, B62D 6/00

(21) Application number: **01103535.9**

(22) Date of filing: **16.02.2001**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **25.02.2000 JP 2000049664**

(71) Applicant: **MITSUBISHI DENKI KABUSHIKI KAISHA**
Tokyo 100-8310 (JP)

(72) Inventors:
- **Kurishige, Masahiko**
  Chiyoda-ku, Tokyo 100 (JP)
- **Inoue, Noriyuki**
  Chiyoda-ku, Tokyo 100 (JP)
- **Nishiyama, Ryoji**
  Chiyoda-ku, Tokyo 100 (JP)
- **Wada, Shunichi**
  Chiyoda-ku, Tokyo 100 (JP)
- **Kifuku, Takayuki**
  Chiyoda-ku, Tokyo 100 (JP)

(74) Representative: **HOFFMANN - EITLE**
Patent- und Rechtsanwälte
Arabellastrasse 4
81925 München (DE)

(54) Electric power steering controller and control method

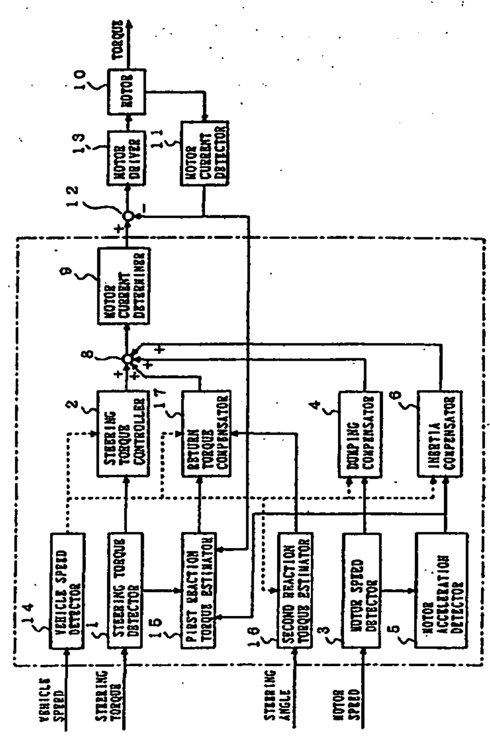
(57) The present invention provides an electric power steering controller and a control method for assisting a driver during handling a steering wheel in a condition of a small road surface reaction torque of a tire by generating an auxiliary return torque (Itire) for letting the steering wheel return to its original position.

The electric power steering controller and the control method is configured in the following.

A first road surface reaction torque (Ttire_est1) is estimated from a steering torque of a driver detected by a steering torque detector (1), a motor acceleration (dω) detected by a motor acceleration detector (5), and a motor current (Imtr) detected by a motor current detector (11).

A second road surface reaction torque (Ttire_est2) is estimated from a steering angle (θhdl) detected by a steering angle sensor, and a vehicle speed (Vx) detected by a vehicle speed detector (14). Then, a first and a second auxiliary return torque signals (Itire_trq, Itire_agl) of the steering wheel are computed from a road surface reaction torque (Ttire_trq), and based on the computed result, a torque (Tmtr) of the motor is controlled into the direction, wherein the steering wheel is returned to its original position.

Fig. 1



EP 1 127 774 A1

Description

Background of the Invention

1. Technical field

[0001] The present invention relates to an electric power steering controller and a control method, and more particularly to an electric power steering controller and a control method for an automotive vehicle to aid a steering force of a driver by generating an assistant torque in a steering system.

2. Background art

[0002] In an example of Japanese laid open Patent No.7-186994, fig. 13 shows a configuration of a conventional electric power steering controller. In this figure a steering torque detector 1 is for detecting a steering torque of a driver. A steering torque control unit 2 is for computing an auxiliary torque based on an output of the steering torque detector 1. A motor speed detector 3 is for detecting a speed of a motor. A damping compensator 4 is for computing a damping compensating signal based on the speed of the motor detected by the motor speed detector 3. A motor acceleration detector 5 is for detecting a acceleration of a motor using an output of the motor speed detector 3. An inertia compensator 6 is for computing an inertia compensating signal based on the acceleration of the motor detected by the motor acceleration detector 5. A judging unit 7 is for judging whether a direction of an output of the steering torque detector 1 and an output of the motor speed detector 3 is identical or not, and for outputting the judged information to the steering torque control unit 2, the damping compensator 4 and the inertia compensator 6. A first adder 8 is for adding the auxiliary torque signal, the damping compensating signal and the inertia compensating signal. A motor current determiner 9 is for computing an aimed current signal from an aimed torque, which is equal to an output of the first adder 8. A motor 10 is for driving a steering mechanism by generating the auxiliary torque approximately proportional to a motor current, which is generated according to an applied voltage. A motor current detector 11 is for detecting a current of the motor 10. A second adder 12 is for computing a difference between the aimed current signal, which is the output of the motor current determiner 9 and the current of the motor detected by the motor current detector 11. A motor driver 13 is for determining and applying a voltage to the motor 10 based on an error signal between the aimed current signal computed by the motor current determiner 9 and the current of the motor detected by the motor current detector 11. And a vehicle speed detector 14 is for detecting a speed of a vehicle, and for outputting the speed of the vehicle herein detected to the steering torque controller 2, the damping compensator 4, and the inertia compensator 6.

[0003] Hereafter, an operation of the electric power steering controller shown in the prior art is to be explained.

[0004] When a driver handles a steering wheel, the steering torque is measured by the steering torque detector 1, and is output to the steering torque controller 2. The steering torque controller 2 computes the auxiliary torque signal approximately proportional to the output signal of the steering torque detector 1, and assists the steering torque of the driver by controlling the motor 10 based on the auxiliary torque signal.

[0005] At this time the judging unit 7 judges whether the direction of an output of the steering torque detector 1 and that of the motor speed detector 3 are same or not, and if the direction is same with each other, both the damping compensator 4 and the inertia compensator 6 are stopped and only the torque controller 2 is operated. The steering torque controller 2 determines the auxiliary torque signal according to the output of the steering torque detector 1 and the speed signal from the vehicle of the vehicle speed detector 14. The aimed torque is determined based on the above auxiliary torque signal, and a motor driving current is determined by the motor current determiner 9.

[0006] When the direction mentioned above is different, the steering torque controller 2 is stopped, and both the damping compensator 4 and the inertia compensator 6 are operated. The aimed torque is determined based on the outputs of the damping compensator 4 and the inertia compensator 6, and the motor driving current is determined by the motor current determiner 9. In this case the direction of the aimed torque is made to coincide with a direction of a motor rotation when the vehicle speed is low, and similarly the direction of the aimed torque is made to oppose to the direction of the motor rotation when the vehicle speed is high. Therefore, when a driver is handling the steering wheel into the direction for the steering angle to increase, the steering torque required by the driver is assisted to mitigate. Moreover, the motor 10 is controlled in the following fashion. That is, when a driver is turning the steering wheel into the direction for the steering angle to decrease, he is assisted to return the steering wheel to its original position when the vehicle speed is low, and is also assisted to prevent the steering wheel from returning excessively when the vehicle speed is high.

[0007] In general, a driver turns the steering wheel at a curvature or a crossing alongside of a road, and then returns the steering wheel for recovering to a straight running by making use of a voluntary return force caused by a road face reaction torque of a tier. However, there are frequently the cases, wherein the road face reaction torque of the tier is small enough causing the road face reaction torque to become smaller than a friction torque in the steering mechanism, and the steering wheel does not return for the vehicle at recovering to the straight road when the vehicle speed is low or a steering operation is minute. Therefore, in this case a driver him-

self has to return the steering wheel by adding the steering torque, hence there is a problem for a steering feeling to be lowered.

[0008] Regarding this point in the prior art, the output of the steering torque detector 1 and the output of the motor speed detector 3 are checked for their coincidence, and if the result is different, the returnable ability of the steering wheel is raised by determining the motor driving current so that the motor 10 is rotated in the same direction with the rotating motor.

[0009] As heretofore explained, in the prior art the steering wheel is in a halted condition and the motor 10 does not rotate unless a driver applies a steering torque to the steering wheel into a returning direction when the steering wheel is handled in a range of the small road surface reaction torque of the tier in case the vehicle is curving a crossing at a low speed or running along a loose curve at a high speed. In this case the judging unit 7 is unable to judge whether or not the direction of the output of the steering torque detector 1 and that of the motor speed detector 3 is identical. Accordingly, there is a problem, wherein the motor driving current can not be determined so as to drive the motor 10 into the same direction with the rotating motor, hence the returnable ability of the steering wheel can not be raised. There is also another problem, wherein a running becomes difficult in a bad condition like a slippery snowy road as no control according to the road surface condition is executed.

Summary of the Invention

[0010] In view of the above, it is the object of the present invention to provide an electric power steering controller and a control method for an automotive vehicle capable of promoting a returnable ability of a steering wheel under the various driving conditions, wherein the steering wheel is returnable without á torque being applied by a driver into a returning direction , and instead a returning control of the steering wheel is executed depending on a steering angle at will of the driver even in a running condition such that a vehicle is turning a crossing at a low speed or curving along a road at a high speed.

[0011] Furthermore, it is another object of the present invention to provide a control method of the electric power steering controller to attain the above object.

[0012] According to this invention ,an electric power steering controller for an automotive vehicle to assist a steering torque of a driver to a steering wheel comprising:

a motor for generating an assistant torque to assist said steering torque of a driver,
a steering torque detecting means for detecting the steering torque of a driver,
a steering angle detecting means for detecting a steering angle of said steering wheel,
a first reaction torque estimating means for estimating a first road surface reaction torque using said steering torque detected by said steering torque detecting means,
a second reaction torque estimating means for estimating a second road surface reaction torque using said steering angle detected by said steering angle detecting means,
a return torque compensating means for computing a first auxiliary return torque signal to control said assistant torque of said motor depending on said first road surface reaction torque estimated by said first reaction torque estimating means, and for computing a second auxiliary return torque signal to control said assistant torque of said motor depending on said second road surface reaction torque estimated by said second reaction torque estimating means,
wherein said return torque compensating means controls said assistant torque of said motor into the direction for said steering wheel to return to its original position by using both said first and said second auxiliary return torque signals.

[0013] In the above steering cotroller, said return torquecompensating means multiplies said second road surface reaction torque estimated by said second reaction torque estimating means by a gain constant, and then limits the maximum value of the above multiplied signal for computing said second auxiliary torque signal.

[0014] Furthermore, in the electric power steering controller said return torque compensating means multiplies said road surface reaction torque detected by said reaction torque estimating means by a gain constant, and then computes said first auxiliary return torque signal by limiting a maximum value of the multiplied signal with a limiter.

[0015] Furthermore ,in the electric power steering controller said return torque compensating means controls said assistant torque of said motor by multiplying said first and said second auxiliary return torque signals by a weight coefficient in a weighting.

[0016] Furthermore ,in the electric power steering controller said weighting made by said return torque compensating means is carried out based on at least one signal of a vehicle speed signal and a bank angle signal on a road surface.

[0017] Furthermore ,in the electric power steering controller said weight coefficient used in weighting is set based on a comparison between said first and said second road surface reaction torques.

[0018] Furthermore ,in the electric power steering controller said weight coefficient is set based on a difference of said first and said second road surface reaction torques.

[0019] Furthermore ,in the electric power steering controller said weight coefficient is set based on a ratio of said first and said second road surface reaction tor-

ques.

[0020] Furthermore ,in the electric power steering controller further comprising a road surface condition judging means for judging a road surface condition using said first and said second road surface reaction torques.

[0021] Furthermore ,in the electric power steering controller said road surface condition judging means compares an absolute value of said first road surface reaction torque with that of said second road surface reaction torque, and judges a road surface condition to be a non-high friction road if said absolute value of said second road surface reaction torque is larger than that of said first road surface reaction torque, and simultaneously if a difference of said absolute values of said first and said second road surface reaction torques exceeds a predetermined value.

[0022] Furthermore ,in the electric power steering controller said road surface condition judging means compares an absolute value of said first road surface reaction torque withthat of said second road surface reaction torque, and judges a road surface condition to be a non-high friction road if said absolute value of said second road surface reaction torque is larger than that of said first road surface reaction torque, and simultaneously if said ratio of said absolute values of said first and said second road surface reaction torques exceeds a predetermined value.

[0023] Furthermore ,in the electric power steering controller a judged result by said road surface condition judging means is used to compensate for said weight coefficient.

[0024] Furthermore ,in the electric power steering controller said return torque compensating means makes said weight coefficient larger which is to be multiplied to said first auxiliary return torque signal if a road surface condition is judged to be said non-high friction road by said road surface condition judging means.

[0025] Furthermore ,in the electric power steering controller said return torque compensating means controls said assistant torque of said motor based on said second auxiliary return torque signal if said road surface condition is judged to be a high friction road by said road surface condition judging means, and also controls said assistant torque of said motor by making said weight coefficient smaller which is to be multiplied to said second auxiliary return torque signal if said road condition is judged to be said non-high friction road by said road surface condition judging means.

[0026] In addition, an electric power steering controller for an automotive vehicle to assist a steering torque of a driver to a steering wheel comprising:

a motor for generating an assistant torque to assist said steering torque of a driver,
a speed detecting means for detecting a speed of the automotive vehicle,
a steering torque detecting means for detecting the steering torque of a driver,
a steering angle detecting means for detecting a steering angle of said steering wheel,
an acceleration detecting means for detecting an acceleration of said motor,
a current detecting means for detecting a current of said motor,
a first reaction torque estimating means for estimating a first road surface reaction torque obtained by letting a signal pass through a low pass filter, wherein the signal is computed from said steering torque detected by said steering torque detecting means, said acceleration of said motor detected by said acceleration detecting means, and said current of said motor detected by said current detecting means,
a second reaction torque estimating means for estimating a second road surface reaction torque using said speed of said automotive vehicle detected by said speed detecting means,
and said steering angle detected by said steering angle detecting means, and
a return torque compensating means for computing a first auxiliary return torque signal to control said assistant torque of said motor depending on said first road surface reaction torque estimated by said first reaction torque estimating means, and for computing a second auxiliary return torque signal to control said assistant torque of said motor depending on said second road surface reaction torque estimated by said second reaction torque estimating means, wherein said return torque compensating means controls said assistant torque of said motor into the direction for said steering wheel to return to its original position by using both said first and said second auxiliary return torque signals.

[0027] In addition ,an electric power steering controller to assist a steering torque of a driver to a steering wheel comprising:

a motor for generating an assistant torque to assist the steering torque of a driver,
a steering torque detecting means for detecting said steering torque of a driver,
a steering angle detecting means for detecting a steering angle of said steering wheel,
a reaction torque estimating means for estimating a road, surface reaction torque using said steering torque detected by said steering torque detecting means, and
a return torque compensating means for computing a first auxiliary return torque signal to control said assistant torque of said motor depending on said road surface reaction torque estimated by said reaction torque estimating means, and for computing a second auxiliary return torque signal to control said assistant torque of said motor depending on said steering angle detected by said steering angle

detecting means,
wherein said return torque compensating means controls an auxiliary torque of said motor into the direction for said steering wheel to return to its original position by using both said first and said second auxiliary return torque signals.

[0028] In addition ,an electric power steering controller for an automotive vehicle to assist a steering torque of a driver to a steering wheel comprising:

a motor for generating an assistant torque to assist the steering torque of a driver,
a speed detecting means for detecting a speed of said automotive vehicle,
a steering torque detecting means for detecting the steering torque of a driver,
a steering angle detecting means for detecting a steering angle of the steering wheel,
an acceleration detecting means for detecting an acceleration of said motor,
a current detecting means for detecting a current of said motor,
a reaction torque estimating means for estimating a road surface reaction torque which is obtained by letting a signal pass through a low pass filter, wherein the signal is computed from said steering torque detected by said steering torque detecting means, said acceleration of said motor detected by said acceleration detecting means, and said current of said motor detected by said current detecting means, and
a return torque compensating means for computing a first auxiliary return torque signal to control said assistant torque of said motor depending on said road surface reaction torque estimated by said reaction torque estimating means, and for computing a second auxiliary return torque signal to control said assistant torque of said motor depending on said speed of said automotive vehicle detected by said speed detecting means and said steering angle detected by said steering angle detecting means,
wherein said return torque compensating means controls said assistant torque of said motor into the direction for said steering wheel to return to its original position by using both said first and said second auxiliary return torque signals.

[0029] In addition ,an electric power steering control method for an automotive vehicle to assist a steering torque of a driver to a steering wheel by using a motor generated torque with steps comprising :

estimating a first road surface reaction torque from a steering torque,
estimating a second road surface reaction torque from a steering angle,
computing a first auxiliary return torque signal from said first road surface reaction torque,
computing a second auxiliary return torque signal from said second road surface reaction torque, and
controlling the assistant torque of said motor depending on said first and said second auxiliary return torque signals to let a steering wheel return to its original position.

[0030] Furthermore ,the electric power steering control method further comprising a step of weighting to said first and said second auxiliary return torque signals for use in controlling said assistant torque of said motor.
[0031] Furthermore ,the electric power steering control method further steps comprising:

judging a road surface condition from said first and said second road surface reaction torques, and
compensating a weight coefficient for weighting according to the judged result.

[0032] As described above, the power steering controller and a control method according to the present invention has the following features.
[0033] A suitable assistant torque of the motor for assisting the steering torque of a driver is generated under various driving conditions as the assistant torque of the motor is controlled into the direction for the steering wheel to return to its original position, wherein the assistant torque of the motor is obtained from the road surface reaction torque or the road surface condition.
[0034] Therefore, a driver is always able to run the automotive vehicle safely in handling the steering wheel in any driving and road conditions.

Brief Description of the Drawings

[0035] Fig.1 is a block diagram showing a configuration of an electric power steering controller in an embodiment 1 according to the present invention.
[0036] Fig.2 is a flow chart of the electric power steering controller explaining an operation in the embodiment 1 according to the present invention.
[0037] Fig.3 is a graph of the electric power steering controller representing characteristics of a second road surface reaction torque in the embodiment 1 according to the present invention.
[0038] Fig.4 is a flow chart of the electric power steering controller explaining an operation in an embodiment 2 according to the present invention.
[0039] Fig.5 is a graph of the electric power steering controller representing a relationship of the estimated values between a first and the second road surface reaction torques in the embodiment 2 according to the present invention.
[0040] Fig.6 is a graph of the electric power steering controller explaining a relationship between a difference of the estimated values of the first and the second road

surface reaction torques, and a weight coefficient in the embodiment 2 according to the present invention.

[0041] Fig.7 is a graph of the electric power steering controller explaining a relationship between a bank angle and the weight coefficient in the embodiment 2 according to the present invention.

[0042] Fig.8 is a block diagram showing a configuration of the electric power steering controller in an embodiment 3 according to the present invention.

[0043] Fig.9 is a flow chart of the electric power steering controller in the embodiment 3 according to the present invention.

[0044] Fig. 10 is a block diagram of the electric power steering controller in an embodiment 4 and 5 according to the present invention.

[0045] Fig.11 is a flow chart explaining an operation of the electric power steering controller in the embodiment 4 according to the present invention.

[0046] Fig.12 is a flow chart explaining an operation of the electric power steering controller in an embodiment 5 according to the present invention.

[0047] Fig.13 is a block diagram showing a configuration of an electric power steering controller in the prior art.

Detailed Description of the Preferred Embodiments

[0048] First of all, a detailed explanation concerning an embodiment 1 is made.

[0049] Fig. 1 is a block diagram showing a configuration of an electric power steering controller in the embodiment 1 according to the present invention.

[0050] In this fig. 1, a steering torque detector 1 as a steering torque detecting means is for detecting a steering torque of a driver, a steering torque controller 2 is for computing an auxiliary torque signal based on an output of the steering torque detector 1, a motor speed detector 3 is for detecting a speed of a motor, a damping compensator 4 is for computing a damping compensating signal based on the speed of the motor detected by the motor speed detector 3, a motor acceleration detector 5 as a motor acceleration detecting means is for detecting an acceleration of the motor using an output of the motor speed detector 3, an inertia compensator 6 is for computing an inertia compensating signal based on the acceleration of the motor detected by the motor acceleration detector 5, a first adder 8 is for computing a sum of the auxiliary torque signal, an auxiliary return torque signal of a steering wheel to be mentioned afterward, the damping compensating signal and the inertia compensating signal, a motor current determiner 9 is for computing an aimed current signal from an aimed torque which is a sum of the auxiliary torque signal and the auxiliary return torque signal of the steering wheel, the damping compensating signal and the inertia compensating signal, a motor 10 is for driving a steering mechanism by producing an assistant torque which is approximately proportional to a current value of the motor generated in accordance with an applied voltage, a motor current detector 11 as a motor current detecting means is for detecting a motor current value, a second adder 12 is for computing a difference between the aimed current signal which is an output of the motor current determiner 9 and the motor current value detected by the motor current detector 11, a motor driver 13 is for determining a voltage to apply to the motor 10 based on an error signal between the aimed current signal computed by the motor current determiner 9 and the motor current value detected by the motor current detector 11, and then applying the determined voltage to the motor 10. And a vehicle speed detector 14 as a vehicle speed detector means for detecting a speed of a vehicle, and then applying the a detected speed to the steering torque controller 2, the damping compensator 4, the inertia compensator 6 and a return torque compensator 17 to be mentioned afterward.

[0051] A first road surface reaction torque estimator 15 including a low pass filter as a first reaction torque estimating means is for estimating a steering angle of a front wheel, that is, a first reaction torque to let the steering wheel return to its original position by using the steering torque of the driver detected by the steering torque detector 1, the motor acceleration detected by the motor acceleration detector 5 and the motor current value detected by the motor current detector 11. A second road surface reaction torque estimator 16 as a second reaction torque estimating means is for estimating a second road surface reaction torque from a steering angle detected by a steering angle sensor built in a steering wheel axis as a steering angle detecting means and the speed of the vehicle detected by the vehicle speed detector 14. A return torque compensator 17 as a return torque compensating means is for computing and outputting an auxiliary return torque signal of the steering wheel to generate an assistant torque to let the steering wheel return to its original position.

[0052] For example, as the motor speed detector 3, a tachometer generator or a rotary encoder, wherein a difference of a pulse output is computed is usable. Furthermore, a reverse electro motive force is capable of being used as the motor speed detector, which is obtained by subtracting a multiplied value of the motor current and a coil resistance from the applied voltage to the motor.

[0053] Fig. 2 is a flow chart of the electric power steering controller explaining an operation in the embodiment 1 according to the present invention.

[0054] Fig.3 is a graph of the electric power steering controller representing characteristics of a second road surface reaction torque in the embodiment 1 according to the present invention.

[0055] In the embodiment 1, the electric power steering controller has the first road surface reaction torque estimator 15 for estimating the first road surface reaction torque and the second road surface reaction torque estimator 16 for estimating the second road surface reac-

tion torque, and generates the auxiliary return torque signal of the steering wheel.

[0056] Hereafter, an explanation is made of the electric power steering controller configured in the embodiment 1 as described above.

[0057] In step S101, a steering torque, Thd1, is read and stored into a memory by the steering torque detector 1, and in step S102, the auxiliary torque signal, Ibase, is computed by the steering torque controller 2. In step S103, the speed signal of the motor by the motor speed detector 3 is read, and in step S104, the motor speed signal is differentiated in the motor acceleration detector 5 for obtaining the motor acceleration signal.

[0058] In step S105, the motor current, Imtr, is read and stored into a memory by the motor current detector 11. In step S106, the first road surface reaction torque is computed in the first road surface reaction torque estimator 15. Then, in step S107, the return torque compensator 17 multiplies the first road surface reaction torque by a single or a plural stage gain constant, and then limits a maximum value of the multiplied signal for computing the first auxiliary return torque signal of the steering wheel, Itire_trq. In step S108, the steering angle θ hdl is read and stored into a memory. In step S109, the vehicle speed is read and stored into a memory by the vehicle speed detector 4. Then, in step S110, the second road surface reaction torque is computed in the second road surface reaction torque estimator 16. In step S111, the return torque compensator17 multiplies the second road surface reaction torque by a single or a plural stage gain constant, and then limits a maximum value of the multiplied signal for computing the second auxiliary return torque signal of the steering wheel (Itire_agl.).

[0059] In step S112, the return torque compensator 17 computes a weight coefficient w by referring to a memorized look-up table holding a fixed value to the vehicle speed. And in step S113, the return torque compensator 17 computes the auxiliary return torque signal of the steering wheel based on a equation (1).

$$\mathrm{Itire} = w \cdot \mathrm{Itire\_trq} + (1-w)\mathrm{Itire\_agl} \qquad (1)$$

[0060] In the equation (1), the weight coefficient depends on the vehicle speed, and its possible range is expressed as $0 \leqq w \leqq 1$.

[0061] In step S114, the motor current determiner 9 computes the aimed torque based on a equation (2),

$$\mathrm{Iref} = \mathrm{Ibase} + \mathrm{Itire} \qquad (2)$$

and then multiplies the aimed torque by a gain constant for computing the aimed current signal, wherein the gain constant is set to be a reciprocal of a torque constant of the motor 10 in steering conversion.

[0062] Hereafter, a function of step S106, wherein the first road surface reaction torque is estimated by the first road surface reaction torque estimator 15., is to be explained in detail.

[0063] First of all, a stationary reaction signal, T'rea_est, is obtained by an equation (3) as below using the steering torque signal, Tsens, the motor acceleration signal, dω, equivalent to a rotating acceleration of a steering axis, and the motor current signal, Imtr.

$$\mathrm{T'rea\_est} = \mathrm{Tsens} + \mathrm{Kt} \cdot \mathrm{Imtr} - \mathrm{J} \cdot d\omega \qquad (3)$$

where

Kt: a torque constant of a motor in steering axis conversion

J : a moment of inertia of a steering mechanism

[0064] Then, a primary filtering computation is carried out based on an equation (4) as shown below using a stationary reaction signal by a low pass filter installed in the first road surface reaction torque estimator 15, and resultantly the first road surface reaction torque signal, Trea_est, is obtained.

$$d\,\mathrm{T'rea\_est}/dt = -\mathrm{Trea\_est}/\mathrm{T1} + \mathrm{T'rea\_est}/\mathrm{T1} \qquad (4)$$

where T1 denotes a time constant of the primary filtering, and a cut- off frequency $fc=1/(2\pi \cdot \mathrm{T1})$ is determined to be in a range from 0.5 to 1.0 Hz.

[0065] A reason why the first road surface reaction torque can be detected from the equation (3) and (4) is explained in the following.

[0066] A motion equation of the steering mechanism is expressed by an equation (5) as shown below.

$$\mathrm{J} \cdot d\omega s/dt = \mathrm{Thdl} + \mathrm{Tmtr} - \mathrm{Tfric} - \mathrm{Treact} \qquad (5)$$

where

dωs/dt: an axial rotation acceleration

Tdhl : a steering torque

Tmtr : a motor output torque converted in steering axis conversion

Tfric : a friction torque in a steering mechanism

Treact : a road surface reaction torque in steering axis conversion

The equation (5) becomes an equation (6) as shown below if it is solved for the road surface reaction torque, Treact.

$$\mathrm{Treact} = \mathrm{Tdhl} + \mathrm{Tmtr} - \mathrm{J} \cdot d\omega s/dt - \mathrm{Tfric} \qquad (6)$$

[0067] Therefore, the first road surface reaction

torque, Treact, is capable of being obtained using the steering torque, the motor output torque, the steering axis rotation acceleration and a friction torque in the steering mechanism. The steering torque signal, Tsens, is capable of being used as the steering torque, Thdl, and a value of the motor current, Imtr, multiplied by the torque constant, Kt, can be used as the motor output torque, Tmtr. Moreover, the motor acceleration signal, dω,is possible to be used as the steering axis rotation acceleration, dωs/dt. In this way, the road surface reaction torque excluding a effect of the friction torque in the steering mechanism, Tfric, can be detected by the equation (3).

[0068] Whereas, the friction torque, Tfric, works as a relay for a rotating speed of the steering mechanism. Moreover, it is widely known in a control engineering field that a function of the relay can be represented equivalently with a gain and a phase using an equivalent linearisation method. Therefore, by adjusting the gain and the phase of the stationary reaction signal, T'rea_est, detected by the equation (3) based on the primary filtering of the equation (4), the first road surface reaction torque signal, Trea_est, is obtained

[0069] More in detail, a filtering is a most frequently used method in adjusting the gain and the phase. In filtering, the gain and the phase are adjustable only above the cut- off frequency range. Namely, if the cut-off frequency is set in a range of the frequency desired to be adjusted multiplied by a factor of 0.5 to 1.0, the gain is approximately adjustable in a range of 1.0 to 0.5, and similarly, the phase in a range of 0.1 to — 20deg. Here, an effect of the friction torque can be cancelled in most cases. In an automotive vehicle, a steering frequency, in general, is in a range of 0.1to 1.0 Hz. Namely, if the cut - off frequency is set to be a steering frequency multiplied by a factor of 0.5 to 1.0 which is equal to 0.05 to 1.0Hz, the effect of the friction torque can be cancelled. Actually, the cut - off frequency is set aiming at most effectively controllable steering frequency based on the detected road surface reaction torque signal.

[0070] Based on a relationship of characteristics as shown in fig.3 between the steering angle and the road surface reaction, step S110 is explained in detail, wherein the second road surface reaction torque estimator 16 estimates the second road surface reaction torque from the steering angle, θ hdl, and the vehicle speed, Vx. In fig.3 there is a relation of curve a<curve b<curve c for the vehicle speed.

[0071] It is due to the relationship as shown below that the road surface reaction torque, that is, a self- aligning torque is calculable from the steering angle.

[0072] As a cornering force works at a backward position of a tier on a grounding surface contacting a road, the tier is always receiving a self- aligning torque during running which lets the vehicle steer into the running direction. In a region of a small skid angle, for example, such as up to 4 to 6 deg., the skid angle and the cornering force are in proportional relationship with each other, and the self-aligning torque is also approximately proportional to the skid angle. Moreover, the skid angle in its small region of the same tier corresponds to the steering angle by one to one relationship when the vehicle speed is fixed. In this manner, the self- aligning torque is obtained from the steering angle.

[0073] The relationship between the skid angle and the steering angle is determined for each vehicle speed, and both the cornering force and the self- aligning torque correspond to the skid angle, therefore, to the steering angle for each vehicle speed by one to one relationship once the road surface condition is determined. Then, the self- aligning torque, that is, the road surface reaction torque, for the steering angle is determined beforehand in terms of each vehicle speed based on the experiment data on the high friction road with a specific vehicle height. Accordingly, the road surface reaction torque is able to be estimated by the second road surface reaction torque estimator 16 which is installed in the electric power steering controller based on the above mentioned relationship.

[0074] Moreover, although the relationship in characteristics in fig.3 is predetermined for the high friction road, wherein μ represents a friction coefficient, a cornering power becomes smaller as μ becomes lower for the road surface condition, and so the self- aligning torque, Trea, given by an equation (7) becomes smaller as μ becomes lower

$$Trea=\xi \cdot Kf \cdot \beta f \qquad (7)$$

where

ξ : a sum of a caster trail and a pneumatic trail
Kf : a cornering power of a front wheel
βf : a skid angle of a front tier

[0075] Therefore, from the relationship (7), the estimated value of the second road surface reaction torque predetermined for the high μ road differs fundamentally from the estimated value of the first road surface reaction torque.

[0076] According to the embodiment 1, by estimating the road surface reaction torque using the first and the second reaction torque estimators, the suitable auxiliary torque of the motor can be generated. And the returnable ability of the steering wheel can be promoted under various driving conditions including a high speed running, wherein a resolution of a steering angle sensor becomes insufficient due to a small width of change in the steering angle.

[0077] Hereafter, a detailed explanation concerning an embodiment 2 is made making use of fig.4 to fig.7

[0078] Fig.4 is a flow chart of the electric power steering controller explaining an operation in the embodiment 2 according to the present invention.

[0079] Fig.5 is a graph of the electric power steering

controller representing a relationship of the estimated values between a first and the second road surface reaction torques in the embodiment 2 according to the present invention.

[0080] Fig.6 is a graph of the electric power steering controller according to the present invention explaining a relationship between a difference of the estimated values of the first and the second road surface reaction torques and a weight coefficient in the embodiment 2. In this fig.6 Δ Ttire is a difference of the estimated values between the first and the second road surface reaction torques, and Δ Ttire0 is a threshold value of an allowable error for the first and the second reaction torques mentioned above. w0 is the weight coefficient corresponding to Δ Ttire0.

[0081] Fig.7 is a graph of the electric power steering controller explaining a relationship between a bank angle and a weight coefficient in the embodiment 2 according to the present invention.

[0082] In the embodiment 2, the weight coefficient w is determined from a characteristic curve in fig.6 based on the difference of the estimated values between the first and the second road surface reaction torques denoted respectively by curve①and curve②in Fig.5.

[0083] Furthermore, as shown in fig. 7, the bank angle used for obtaining the weight coefficient is an estimated value of the bank angle computed in a brake control unit (abbreviated for explanation) in case there exists the bank angle which is a leaning angle for the running direction. In fig.3, the characteristic relationship is based on a zero bank angle, and an error of the estimated value of the second road surface reaction torque is produced as the bank angle becomes large.

[0084] Therefore, in this case the weight coefficient is made to be larger for reflecting an error effect in the estimated value of the above reaction torque.

[0085] An operation of the electrical power steering controller in the embodiment 2 is executed in the following based on fig.2.

[0086] A processing function of step S201 to S211 is same with step S101 to S111. In steps following step S211, steps are carried out by the return torque compensator 17 as explained hereafter.. Firstly, in step S212 a difference of the estimated values between the first and the second road surface reaction torques is computed by an equation (8).

$$\Delta Ttire = Ttire\_est2 - Ttire\_est1 \quad (8)$$

where

Ttire_est1:	an estimated value of the first road surface reaction torque
Ttire_est2:	an estimated value of the second road surface reaction torque

[0087] Secondly, in step S213 the difference from step S212 is compared with a threshold value, Δ Ttire0. A process advances to step 214 if Δ Ttire is larger than Δ Ttire0, and the weight coefficient w is determined from Δ Ttire by referring to a memorized look - up table, wherein a fixed value is stored beforehand. If Δ Ttire is smaller than or equal to Δ Ttire0, a processing proceeds to step S215, and the weight coefficient w is set to be w0. In step S216 following step 214 or step 215, the auxiliary return torque signal of the steering wheel is computed by the equation (1).

[0088] Then, in step S217 an aimed torque signal is obtained by the motor current determiner 9 using the equation (2), and an aimed current is obtained from multiplying the aimed torque by a gain constant. In this case, the gain constant is set equal to be a reciprocal of a torque constant of the motor 10 in steering conversion

[0089] In the embodiment 2, as a weighting is done for the estimated values of both the first and the second road surface reaction torques, a suitable auxiliary return torque signal of the steering wheel is given even when the bank angle is existing.

[0090] From here, an explanation of an embodiment 3 according to the present invention is made using fig. 8 and fig.9.

[0091] Fig.8 is a block diagram showing a configuration of the electric power steering controller in the embodiment 3 according to the present invention. In this fig.8, a denotation of 1 to 6, 8 to 15 and 17 is same with that of fig.1.

[0092] In the embodiment 3, a second auxiliary return torque signal of the steering wheel is directly derived from the steering angle and the vehicle speed. Namely, an auxiliary return torque signal of the steering wheel is computed from the estimated values of both the first and the second auxiliary return torque signals derived from the estimated value of the first road surface reaction torque.

[0093] Fig.9 is a flow chart of the electric power steering controller in the embodiment 3 according to the present invention.

[0094] Hereafter, an operation of the electric power steering controller in the embodiment 3 is explained based on fig. 9.

[0095] A processing of step S301 to S305 is same with that of step S101 to S105. In step S306, the steering angle θ dh1 is read and stored into a memory. In step S307, the vehicle speed, Vx, is read by the vehicle speed detector 14 and stored into a memory. In step S308, the first road surface reaction torque is estimated in the first road surface reaction torque estimator 15. Then in step S309, the first auxiliary return torque signal of the steering wheel,

[0096] Itire_trq, is computed ,and in step S310, the second auxiliary return torque signal of the steering wheel is computed from the steering angle, θ dh1, and the vehicle speed, Vx. In step S311, the weight coefficient is computed, and in step S312, the auxiliary return torque signal of the steering wheel is derived by the

equation (1). And finally in step S313, an aimed torque is derived by the motor current determiner 9 using the equation (2), and the aimed torque is multiplied by a gain constant for obtaining an aimed current. In this case, the gain constant is set equal to be a reciprocal of the torque constant of the motor in steering conversion.

[0097] According to the embodiment 3, the second auxiliary return torque signal of the steering wheel is directly derived from the steering angle and the vehicle speed, and hence, the second road surface reaction torque estimator can be abbreviated.

[0098] Hereafter, an operation of the electric power steering controller in an embodiment 4 according to the present invention is explained based on fig.10 and fig 11.

[0099] Fig. 10 is a block diagram of the electric power steering controller according to the present invention.

[0100] In fig.10, a denotation of 1 to 6 and 8 to 17 is same with that of fig. 1. In this fig.10, a road surface judging unit 18 is for judging a road surface condition from the estimated values of both the first and the second road surface reaction torques.

[0101] Fig. 11 is a flow chart explaining an operation of the electric power steering controller in the embodiment 4 according to the present invention.

[0102] A feature of the embodiment 4 lies in an installment of the road surface judging unit 18.

[0103] An estimated value of the first road surface reaction torque becomes small when a road surface μ ,a friction coefficient, is small as the above estimation value is derived from an actual road surface reaction. Contrary to this, as an absolute value of an estimated value of the second road surface reaction torque is based on a model with a high μ road, the absolute value never becomes small when a road μ is small.

[0104] Therefore, when the estimated value of the second road surface reaction torque is larger than that of the first road surface reaction torque by a predetermined value in terms of a difference or a ratio, a road surface can be judged to be a low μ road.

[0105] In case a road surface condition is judged to be the low μ road in the embodiment 4, the weight coefficient is made to be larger in computing the first auxiliary return torque signal of the steering wheel.

[0106] From here, the electric power steering controller in the embodiment 4 is explained using fig .11.

[0107] Step S401 to S411 is similarly processed as in step S101 to step S111. In step S412, the road surface judging unit 18 judges a road μ from the estimated values of the first and the second road surface reaction torques. In step S413, if the road surface condition is judged to be a high μ road by the road surface judging unit 18, the return torque compensator 17 determines a weight coefficient, w, by referring to a look-up table for the vehicle speed. Whereas, if the result is judged to be a non - high μ road in step S412, the weight coefficient is set to be larger than that of high μ road by referring to the look- up table for the vehicle speed in step S414. And in step S415 after step S413 or S414 is executed, the return torque compensator 17 computes the auxiliary return torque signal of the steering wheel by the equation (1).

[0108] Then, in step S416, an aimed torque is computed by the equation (2), and an aimed current is derived from the aimed torque multiplied by a gain constant by the motor current determiner 9. In this case, the gain constant is set equal to a reciprocal of the torque constant of the motor in steering conversion.

[0109] In the embodiment 4, as the weight coefficient is changed according to the road surface condition in computing the auxiliary return torque signal of the steering wheel, a suitable auxiliary return torque signal of the steering wheel can be given regardless of the road surface condition. From here, the electric power steering controller in an embodiment 5 is explained using fig .12.

[0110] In the embodiment 5, a second auxiliary return torque signal is made to be small when a road surface is judged to be a non—high μ road.

[0111] Fig.12 is a flow chart explaining an operation of the electric power steering controller in the embodiment 5 according to the present invention. In this fig. 12, a processing of step S501 to S511 is same with step S401 to S411 in fig,11. In step S512 following step S511, a road surface μ is judged from the estimated values of the first and the second road surface reactions by the road surface judging unit 18.

[0112] If the judged result from the road surface condition judging unit 18 is a high μ road, an auxiliary return torque signal of the steering wheel is computed by an equation,

$$Itire=Itire\_agl$$

and is made equal to the second auxiliary return torque signal in step S513. If the above result is a non — high μ road, the auxiliary return torque signal of the steering wheel is computed by an equation,

$$Itire=Itire\_agl*kcomp$$

where

kcomp: a coefficient ($0 \le kcomp < 1$)

and the second auxiliary return torque signal is made to be small including 0.

[0113] Then, in step S515, an aimed torque is computed by the equation (2), and an aimed current is derived from the aimed torque multiplied by a gain constant by the motor current determiner 9. In this case, the gain constant is set equal to a reciprocal of the torque constant of the motor in steering conversion.

[0114] According to the embodiment 5, when the road

surface is a non—high μ road, the auxiliary return torque signal of the steering wheel is made small, and hence, a suitable auxiliary return torque signal of the steering wheel can be given regardless of a road surface condition.

Claims

1. An electric power steering controller for an automotive vehicle to assist a steering torque of a driver to a steering wheel comprising:

   a motor for generating an assistant torque to assist said steering torque of a driver
   a steering torque detecting means for detecting the steering torque of a driver,
   a steering angle detecting means for detecting a steering angle of said steering wheel,
   a first reaction torque estimating means for estimating a first road surface reaction torque using said steering torque detected by said steering torque detecting means,
   a second reaction torque estimating means for estimating a second road surface reaction torque using said steering angle detected by said steering angle detecting means,
   a return torque compensating means for computing a first auxiliary return torque signal to control said assistant torque of said motor depending on said first road surface reaction torque estimated by said first reaction torque estimating means, and for computing a second auxiliary return torque signal to control said assistant torque of said motor depending on said second road surface reaction torque estimated by said second reaction torque estimating means,
   wherein said return torque compensating means controls said assistant torque of said motor into the direction for said steering wheel to return to its original position by using both said first and said second auxiliary return torque signals.

2. The electric power steering controller in claim 1,wherein said return torque compensating means multiplies said second road surface reaction torque estimated by said second reaction torque estimating means by a gain constant, and then limits the maximum value of the above multiplied signal for computing said second auxiliary torque signal.

3. The electric power steering controller in claim 1, wherein said return torque compensating means multiplies said road surface reaction torque detected by said reaction torque estimating means by a gain constant, and then computes said first auxiliary return torque signal by limiting a maximum value of the multiplied signal with a limiter.

4. The electric power steering controller in claim 1, wherein said return torque compensating means controls said assistant torque of said motor by multiplying said first and said second auxiliary return torque signals by a weight coefficient in a weighting.

5. An electric power steering controller for an automotive vehicle to assist a steering torque of a driver to a steering wheel comprising:

   a motor for generating an assistant torque to assist said steering torque of a driver,
   a speed detecting means for detecting a speed of the automotive vehicle,
   a steering torque detecting means for detecting the steering torque of a driver,
   a steering angle detecting means for detecting a steering angle of said steering wheel,
   an acceleration detecting means for detecting an acceleration of said motor,
   a current detecting means for detecting a current of said motor,
   a first reaction torque estimating means for estimating a first road surface reaction torque obtained by letting a signal pass through a low pass filter, wherein the signal is computed from said steering torque detected by said steering torque detecting means, said acceleration of said motor detected by said acceleration detecting means, and said current of said motor detected by said current detecting means,
   a second reaction torque estimating means for estimating a second road surface reaction torque using said speed of said automotive vehicle detected by said speed detecting means, and said steering angle detected by said steering angle detecting means, and
   a return torque compensating means for computing a first auxiliary return torque signal to control said assistant torque of said motor depending on said first road surface reaction torque estimated by said first reaction torque estimating means, and for computing a second auxiliary return torque signal to control said assistant torque of said motor depending on said second road surface reaction torque estimated by said second reaction torque estimating means, wherein said return torque compensating means controls said assistant torque of said motor into the direction for said steering wheel to return to its original position by using both said first and said second auxiliary return torque signals.

6. An electric power steering controller to assist a

steering torque of a driver to a steering wheel comprising:
a motor for generating an assistant torque to assist the steering torque of a driver,

a steering torque detecting means for detecting said steering torque of a driver,
a steering angle detecting means for detecting a steering angle of said steering wheel,
a reaction torque estimating means for estimating a road,
surface reaction torque using said steering torque detected by said steering torque detecting means, and
a return torque compensating means for computing a first auxiliary return torque signal to control said assistant torque of said motor depending on said road surface reaction torque estimated by said reaction torque estimating means, and for computing a second auxiliary return torque signal to control said assistant torque of said motor depending on said steering angle detected by said steering angle detecting means,
wherein said return torque compensating means controls an auxiliary torque of said motor into the direction for said steering wheel to return to its original position by using both said first and said second auxiliary return torque signals.

7. An electric power steering controller for an automotive vehicle to assist a steering torque of a driver to a steering wheel comprising:

a motor for generating an assistant torque to assist the steering torque of a driver,
a speed detecting means for detecting a speed of said automotive vehicle,
a steering torque detecting means for detecting the steering torque of a driver,
a steering angle detecting means for detecting a steering angle of the steering wheel,
an acceleration detecting means for detecting an acceleration of said motor,
a current detecting means for detecting a current of said motor,
a reaction torque estimating means for estimating a road surface reaction torque which is obtained by letting a signal pass through a low pass filter, wherein the signal is computed from said steering torque detected by said steering torque detecting means, said acceleration of said motor detected by said acceleration detecting means, and said current of said motor detected by said current detecting means, and
a return torque compensating means for computing a first auxiliary return torque signal to control said assistant torque of said motor depending on said road surface reaction torque estimated by said reaction torque estimating means, and for computing a second auxiliary return torque signal to control said assistant torque of said motor depending on said speed of said automotive vehicle detected by said speed detecting means and said steering angle detected by said steering angle detecting means,
wherein said return torque compensating means controls said assistant torque of said motor into the direction for said steering wheel to return to its original position by using both said first and said second auxiliary return torque signals.

8. An electric power steering control method for an automotive vehicle to assist a steering torque of a driver to a steering wheel by using a motor generated torque with steps comprising :

estimating a first road surface reaction torque from a steering torque,
estimating a second road surface reaction torque from a steering angle,
computing a first auxiliary return torque signal from said first road surface reaction torque,
computing a second auxiliary return torque signal from said second road surface reaction torque, and
controlling the assistant torque of said motor depending on said first and said second auxiliary return torque signals to let a steering wheel return to its original position.

9. The electric power steering control method in claim 8 further comprising a step of weighting to said first and said second auxiliary return torque signals for use in controlling said assistant torque of said motor.

Fig. 1

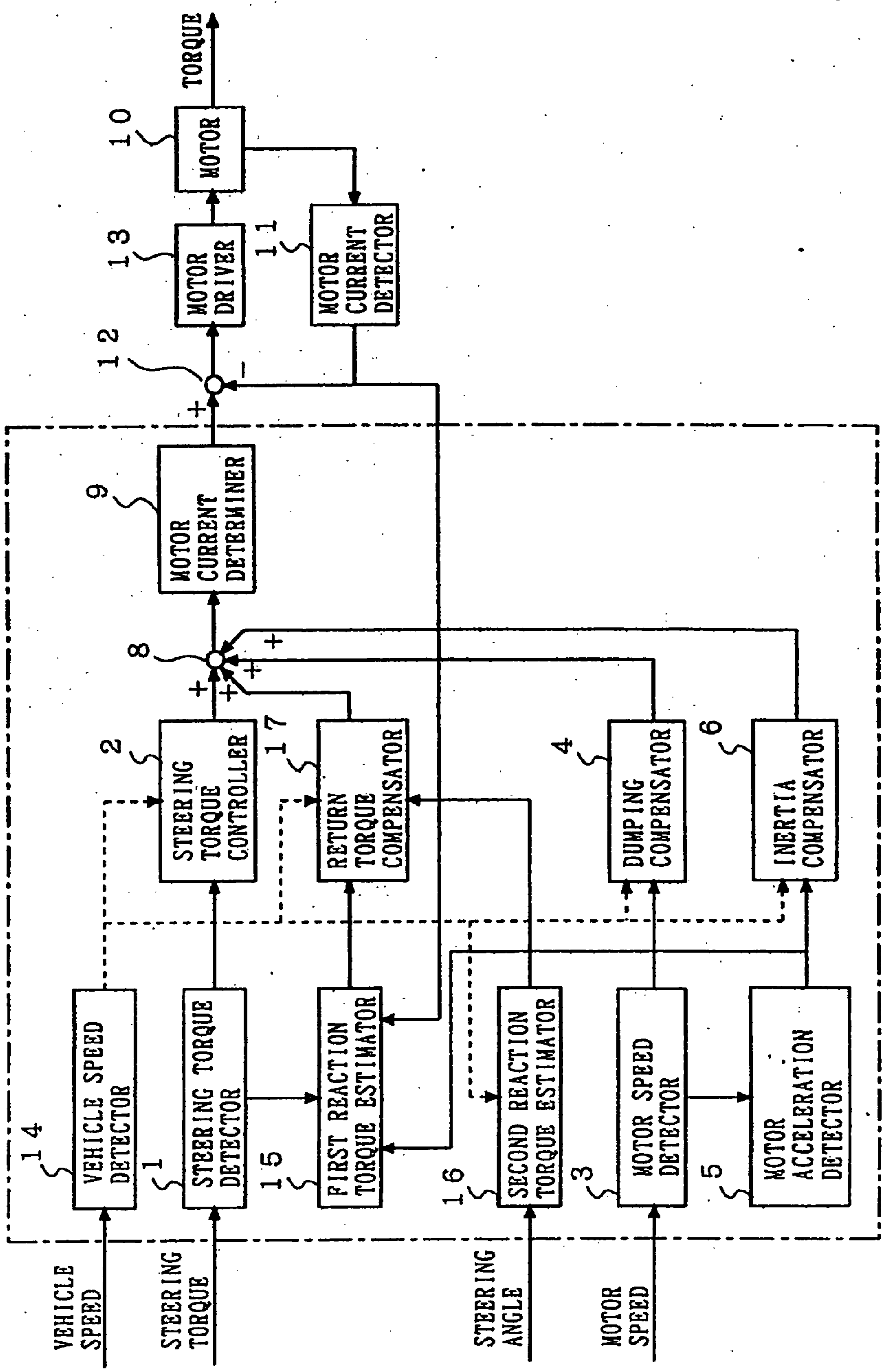

TORQUE
10
MOTOR
13
MOTOR DRIVER
11
MOTOR CURRENT DETECTOR
12
+
−
9
MOTOR CURRENT DETERMINER
8
+
+
+
+
2
STEERING TORQUE CONTROLLER
17
RETURN TORQUE COMPENSATOR
4
DUMPING COMPENSATOR
6
INERTIA COMPENSATOR
14
VEHICLE SPEED DETECTOR
1
STEERING TORQUE DETECTOR
15
FIRST REACTION TORQUE ESTIMATOR
16
SECOND REACTION TORQUE ESTIMATOR
3
MOTOR SPEED DETECTOR
5
MOTOR ACCELERATION DETECTOR
VEHICLE SPEED
STEERING TORQUE
STEERING ANGLE
MOTOR SPEED

Fig.2

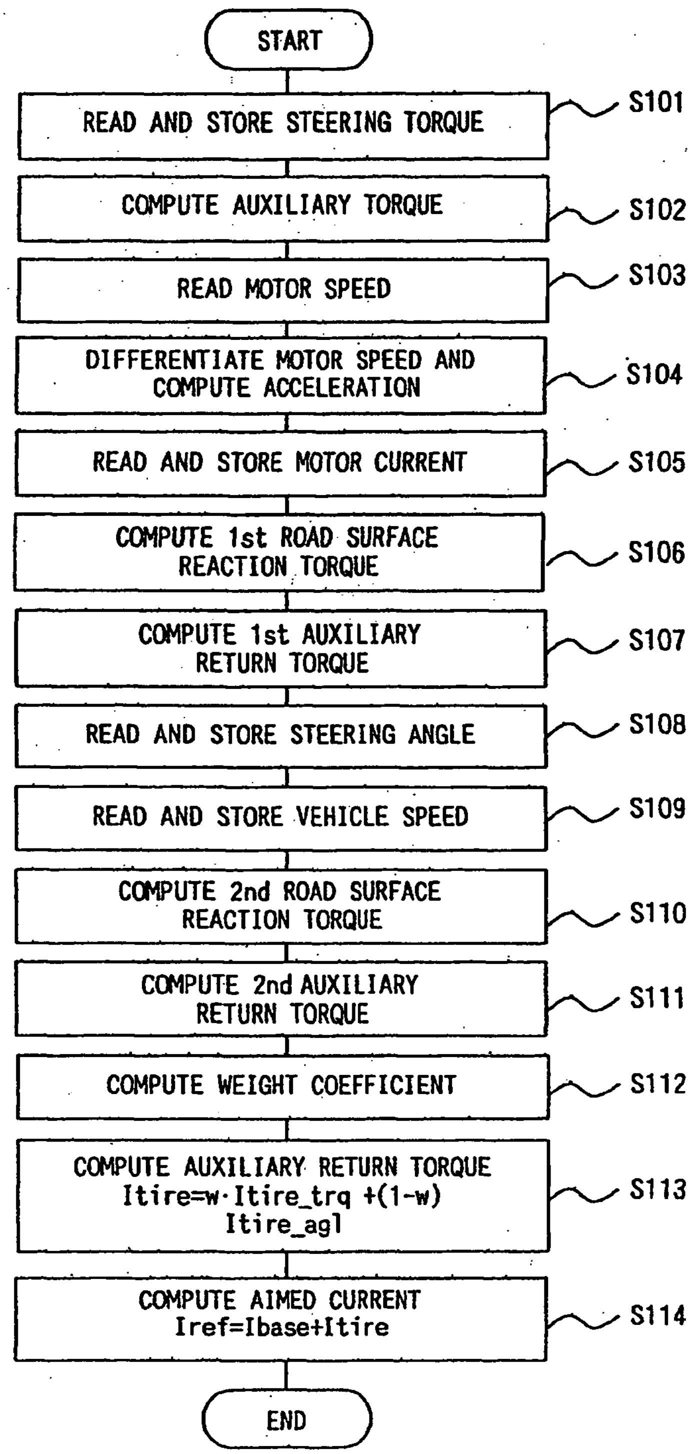

START
READ AND STORE STEERING TORQUE
S101
COMPUTE AUXILIARY TORQUE
S102
READ MOTOR SPEED
S103
DIFFERENTIATE MOTOR SPEED AND COMPUTE ACCELERATION
S104
READ AND STORE MOTOR CURRENT
S105
COMPUTE 1st ROAD SURFACE REACTION TORQUE
S106
COMPUTE 1st AUXILIARY RETURN TORQUE
S107
READ AND STORE STEERING ANGLE
S108
READ AND STORE VEHICLE SPEED
S109
COMPUTE 2nd ROAD SURFACE REACTION TORQUE
S110
COMPUTE 2nd AUXILIARY RETURN TORQUE
S111
COMPUTE WEIGHT COEFFICIENT
S112
COMPUTE AUXILIARY RETURN TORQUE
Itire=w·Itire_trq +(1-w) Itire_agl
S113
COMPUTE AIMED CURRENT
Iref=Ibase+Itire
S114
END

Fig. 3

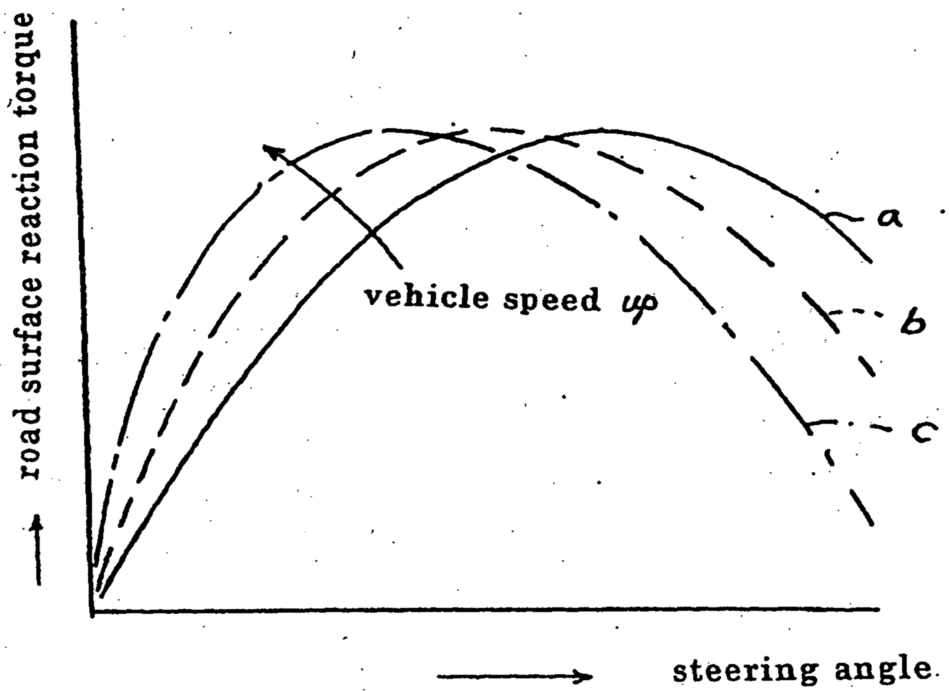

road surface reaction torque
vehicle speed up
a
b
c
steering angle

Fig.4

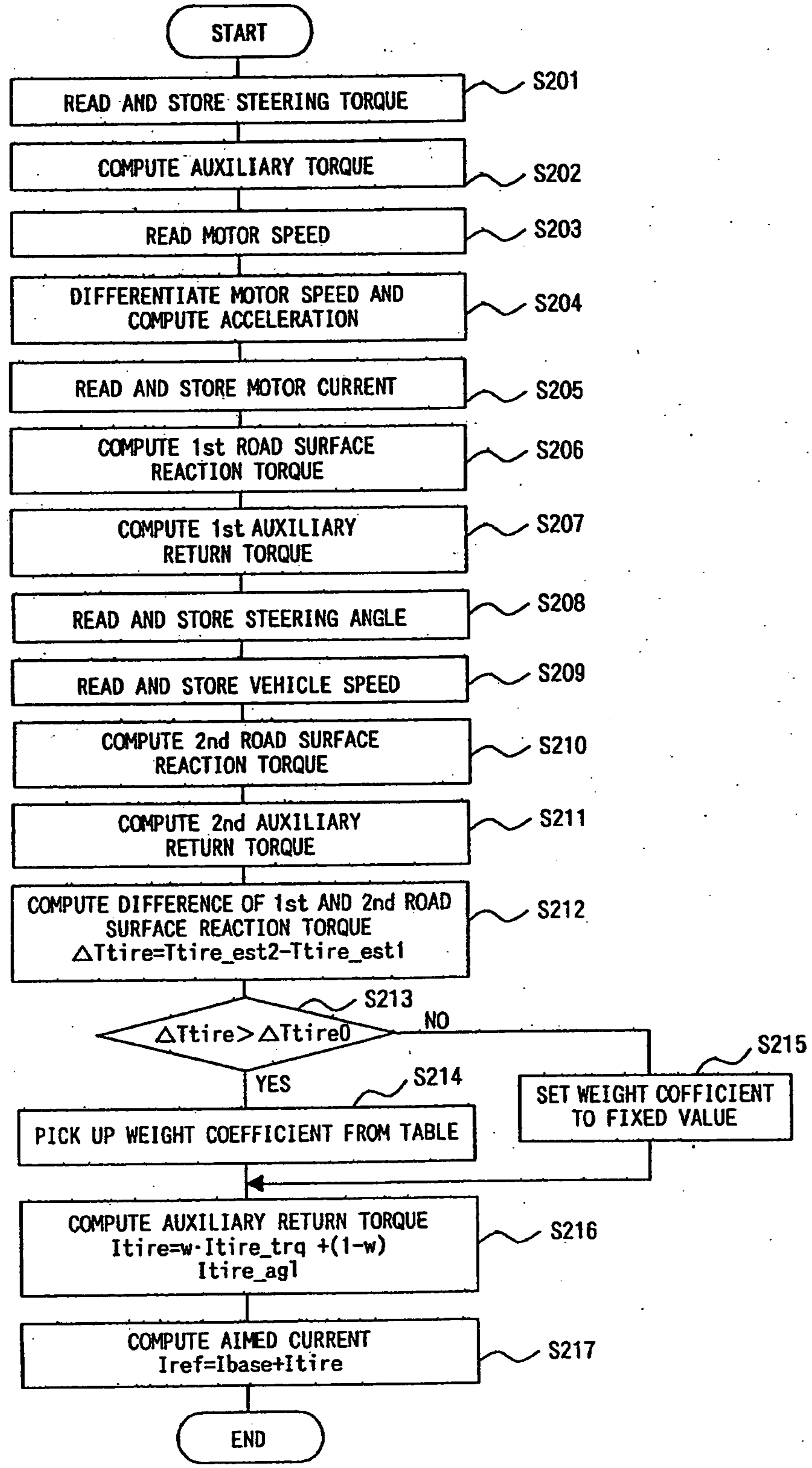

START
READ AND STORE STEERING TORQUE
S201
COMPUTE AUXILIARY TORQUE
S202
READ MOTOR SPEED
S203
DIFFERENTIATE MOTOR SPEED AND COMPUTE ACCELERATION
S204
READ AND STORE MOTOR CURRENT
S205
COMPUTE 1st ROAD SURFACE REACTION TORQUE
S206
COMPUTE 1st AUXILIARY RETURN TORQUE
S207
READ AND STORE STEERING ANGLE
S208
READ AND STORE VEHICLE SPEED
S209
COMPUTE 2nd ROAD SURFACE REACTION TORQUE
S210
COMPUTE 2nd AUXILIARY RETURN TORQUE
S211
COMPUTE DIFFERENCE OF 1st AND 2nd ROAD SURFACE REACTION TORQUE
ΔTtire=Ttire_est2-Ttire_est1
S212
S213
ΔTtire>ΔTtire0
NO
YES
S214
PICK UP WEIGHT COEFFICIENT FROM TABLE
S215
SET WEIGHT COFFICIENT TO FIXED VALUE
COMPUTE AUXILIARY RETURN TORQUE
Itire=w·Itire_trq +(1-w) Itire_agl
S216
COMPUTE AIMED CURRENT
Iref=Ibase+Itire
S217
END

Fig. 5

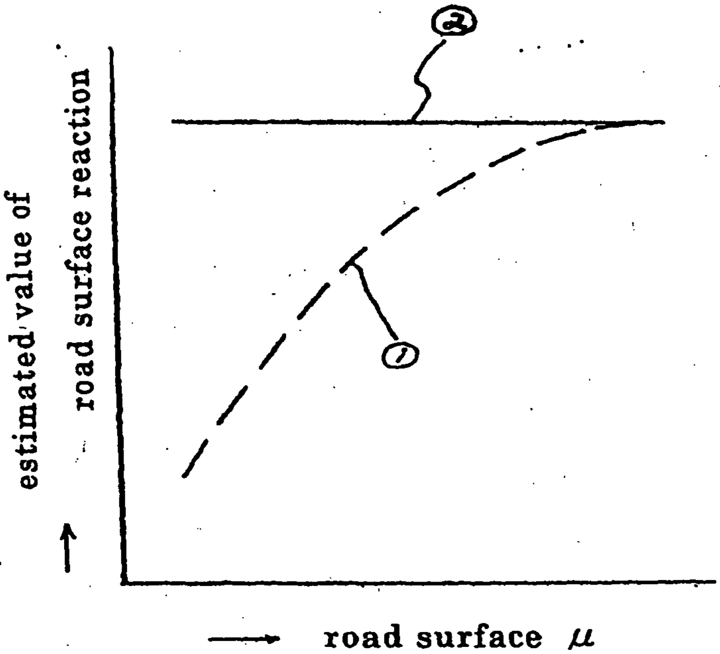

②
①
estimated value of road surface reaction
road surface μ

Fig. 6

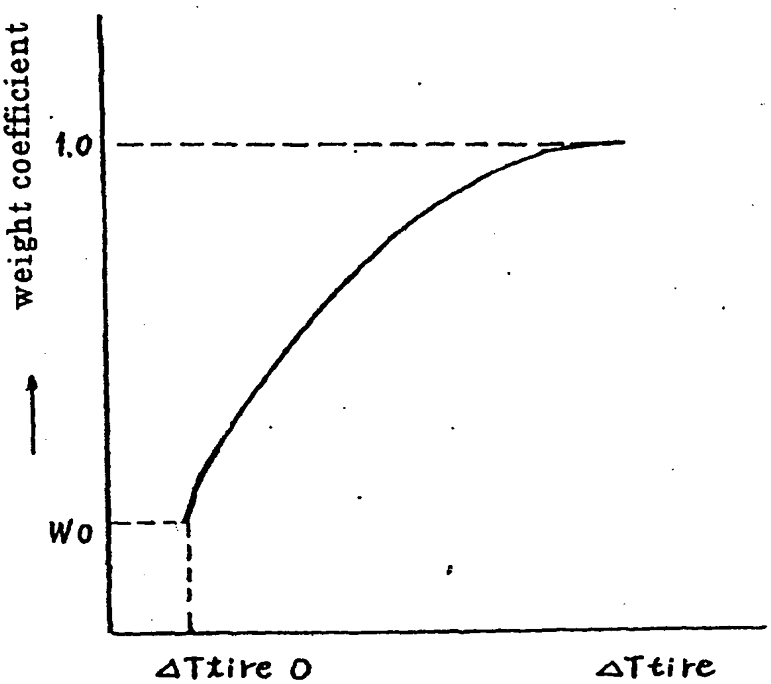

weight coefficient
1.0
Wo
ΔTtire 0
ΔTtire

Fig. 7

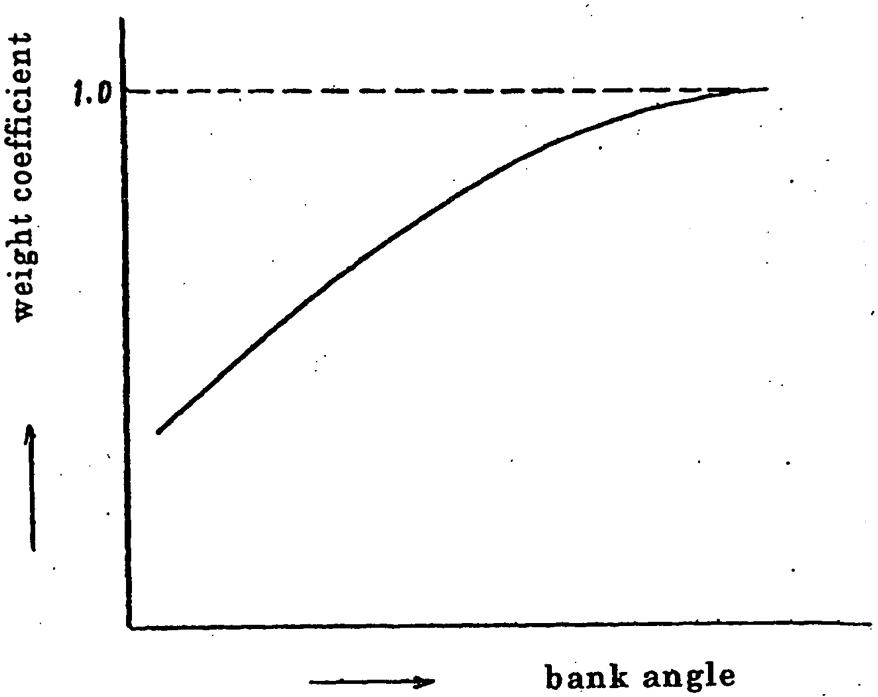


Fig. 8

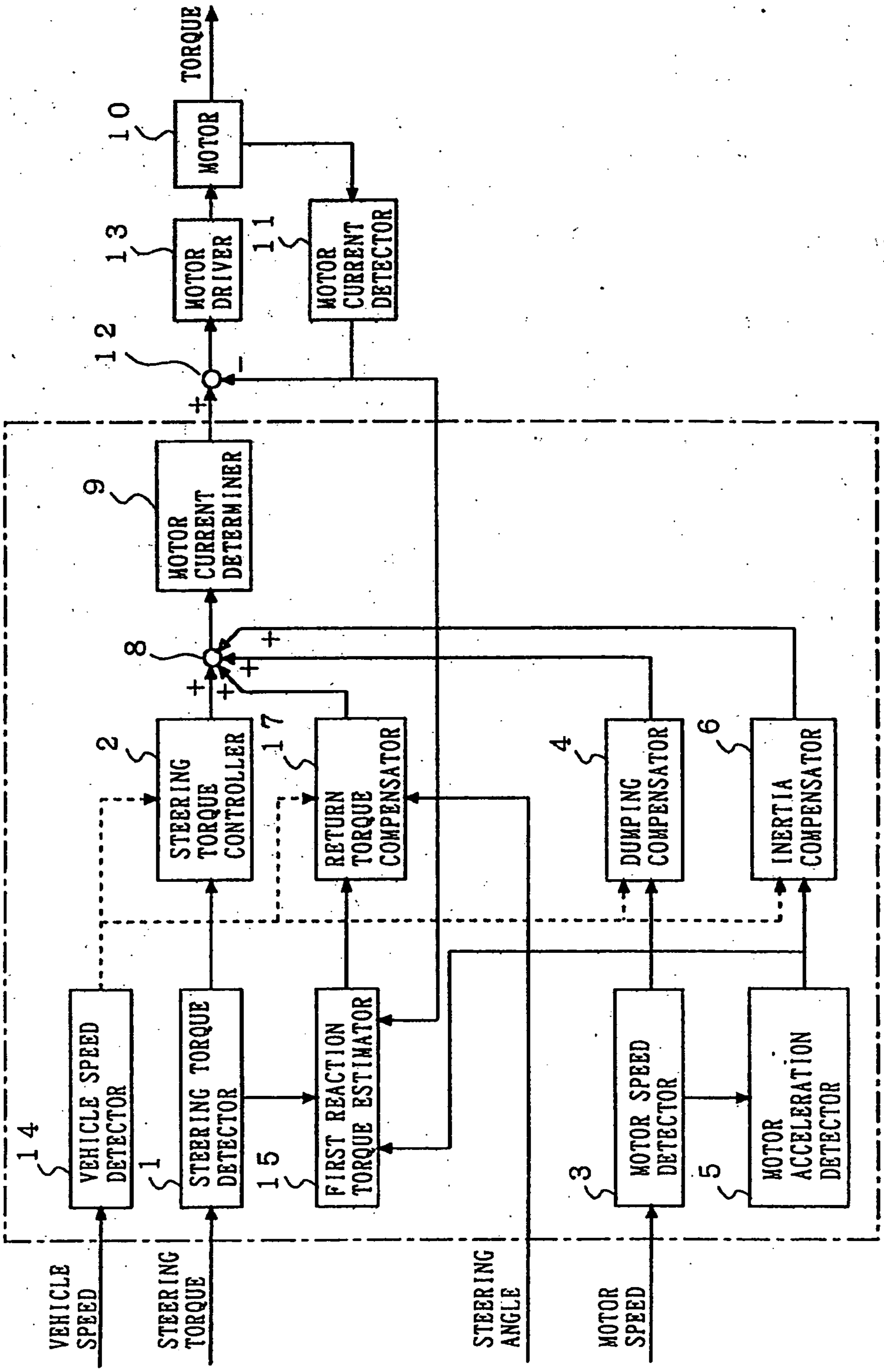

TORQUE
10
MOTOR
13
MOTOR DRIVER
11
MOTOR CURRENT DETECTOR
12
9
MOTOR CURRENT DETERMINER
8
2
STEERING TORQUE CONTROLLER
17
RETURN TORQUE COMPENSATOR
4
DUMPING COMPENSATOR
6
INERTIA COMPENSATOR
14
VEHICLE SPEED DETECTOR
1
STEERING TORQUE DETECTOR
15
FIRST REACTION TORQUE ESTIMATOR
3
MOTOR SPEED DETECTOR
5
MOTOR ACCELERATION DETECTOR
VEHICLE SPEED
STEERING TORQUE
STEERING ANGLE
MOTOR SPEED

Fig.9

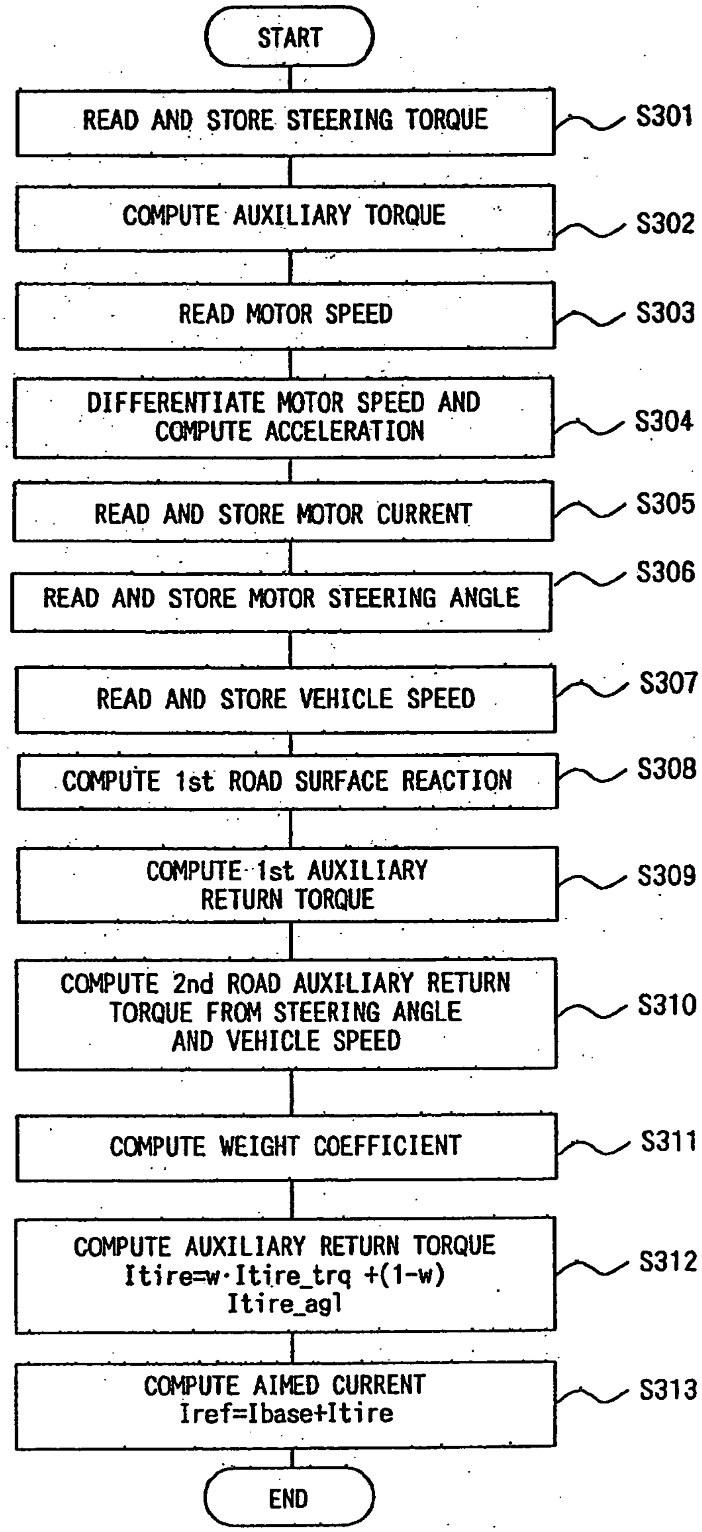

START
READ AND STORE STEERING TORQUE
S301
COMPUTE AUXILIARY TORQUE
S302
READ MOTOR SPEED
S303
DIFFERENTIATE MOTOR SPEED AND COMPUTE ACCELERATION
S304
READ AND STORE MOTOR CURRENT
S305
READ AND STORE MOTOR STEERING ANGLE
S306
READ AND STORE VEHICLE SPEED
S307
COMPUTE 1st ROAD SURFACE REACTION
S308
COMPUTE 1st AUXILIARY RETURN TORQUE
S309
COMPUTE 2nd ROAD AUXILIARY RETURN TORQUE FROM STEERING ANGLE AND VEHICLE SPEED
S310
COMPUTE WEIGHT COEFFICIENT
S311
COMPUTE AUXILIARY RETURN TORQUE Itire=w·Itire_trq +(1-w) Itire_agl
S312
COMPUTE AIMED CURRENT Iref=Ibase+Itire
S313
END

Fig. 10

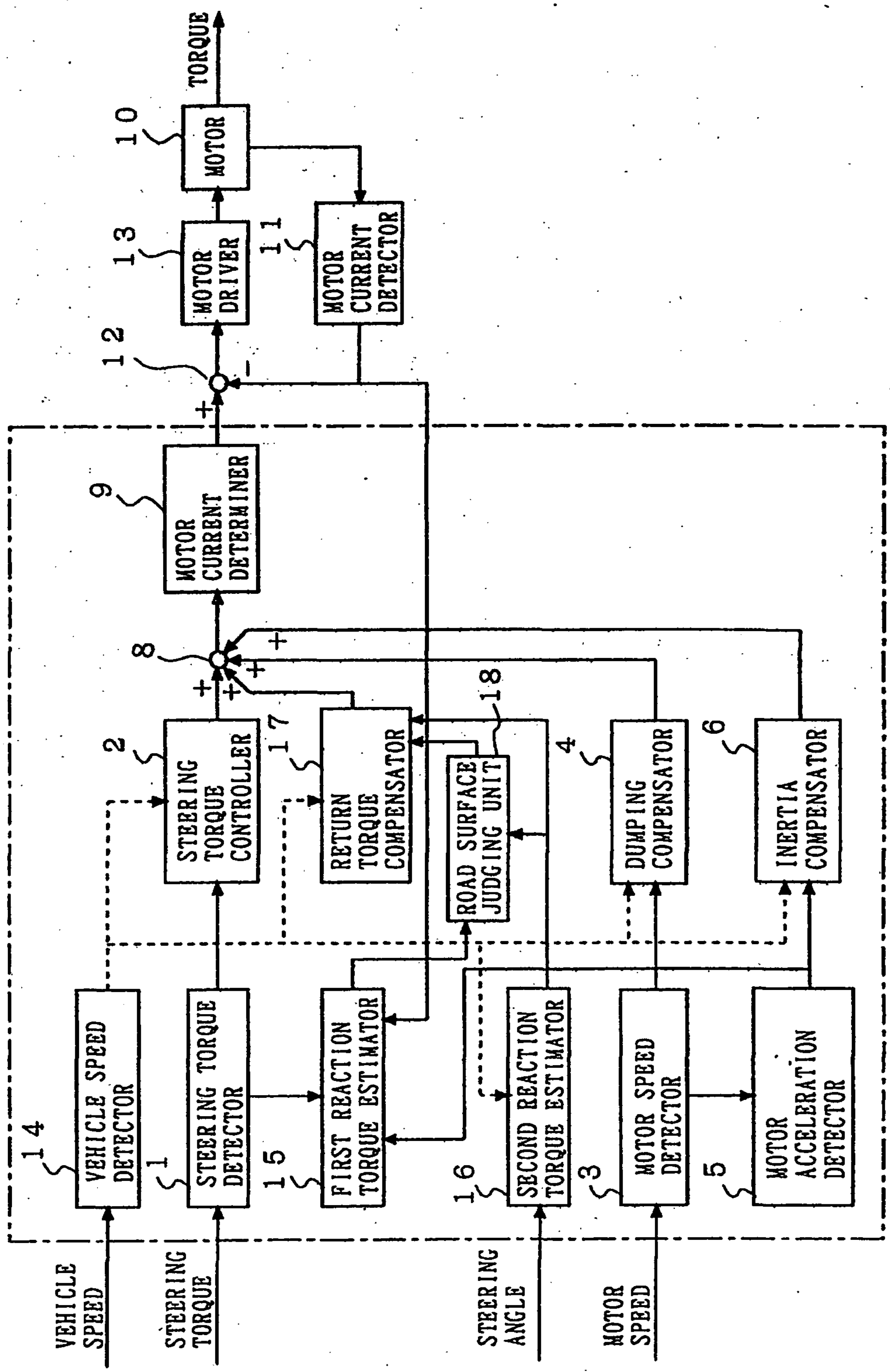

TORQUE
10
MOTOR
13
MOTOR DRIVER
11
MOTOR CURRENT DETECTOR
12
9
MOTOR CURRENT DETERMINER
8
2
STEERING TORQUE CONTROLLER
17
RETURN TORQUE COMPENSATOR
18
ROAD SURFACE JUDGING UNIT
4
DUMPING COMPENSATOR
6
INERTIA COMPENSATOR
14
VEHICLE SPEED DETECTOR
1
STEERING TORQUE DETECTOR
15
FIRST REACTION TORQUE ESTIMATOR
16
SECOND REACTION TORQUE ESTIMATOR
3
MOTOR SPEED DETECTOR
5
MOTOR ACCELERATION DETECTOR
VEHICLE SPEED
STEERING TORQUE
STEERING ANGLE
MOTOR SPEED

Fig.11

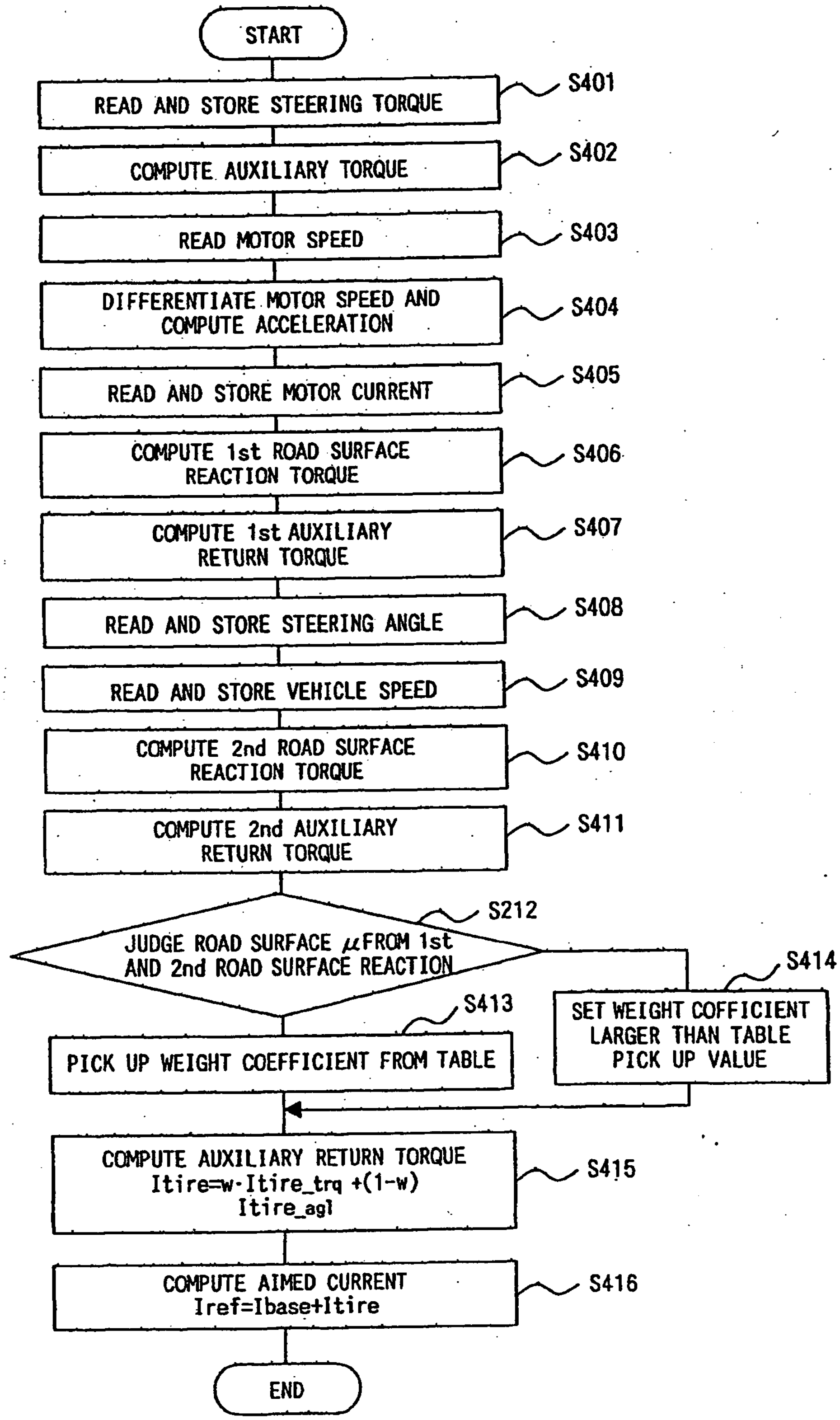

START
READ AND STORE STEERING TORQUE
S401
COMPUTE AUXILIARY TORQUE
S402
READ MOTOR SPEED
S403
DIFFERENTIATE MOTOR SPEED AND COMPUTE ACCELERATION
S404
READ AND STORE MOTOR CURRENT
S405
COMPUTE 1st ROAD SURFACE REACTION TORQUE
S406
COMPUTE 1st AUXILIARY RETURN TORQUE
S407
READ AND STORE STEERING ANGLE
S408
READ AND STORE VEHICLE SPEED
S409
COMPUTE 2nd ROAD SURFACE REACTION TORQUE
S410
COMPUTE 2nd AUXILIARY RETURN TORQUE
S411
S212
JUDGE ROAD SURFACE μ FROM 1st AND 2nd ROAD SURFACE REACTION
S413
PICK UP WEIGHT COEFFICIENT FROM TABLE
S414
SET WEIGHT COFFICIENT LARGER THAN TABLE PICK UP VALUE
COMPUTE AUXILIARY RETURN TORQUE
Itire=w·Itire_trq +(1-w) Itire_agl
S415
COMPUTE AIMED CURRENT
Iref=Ibase+Itire
S416
END

Fig.12

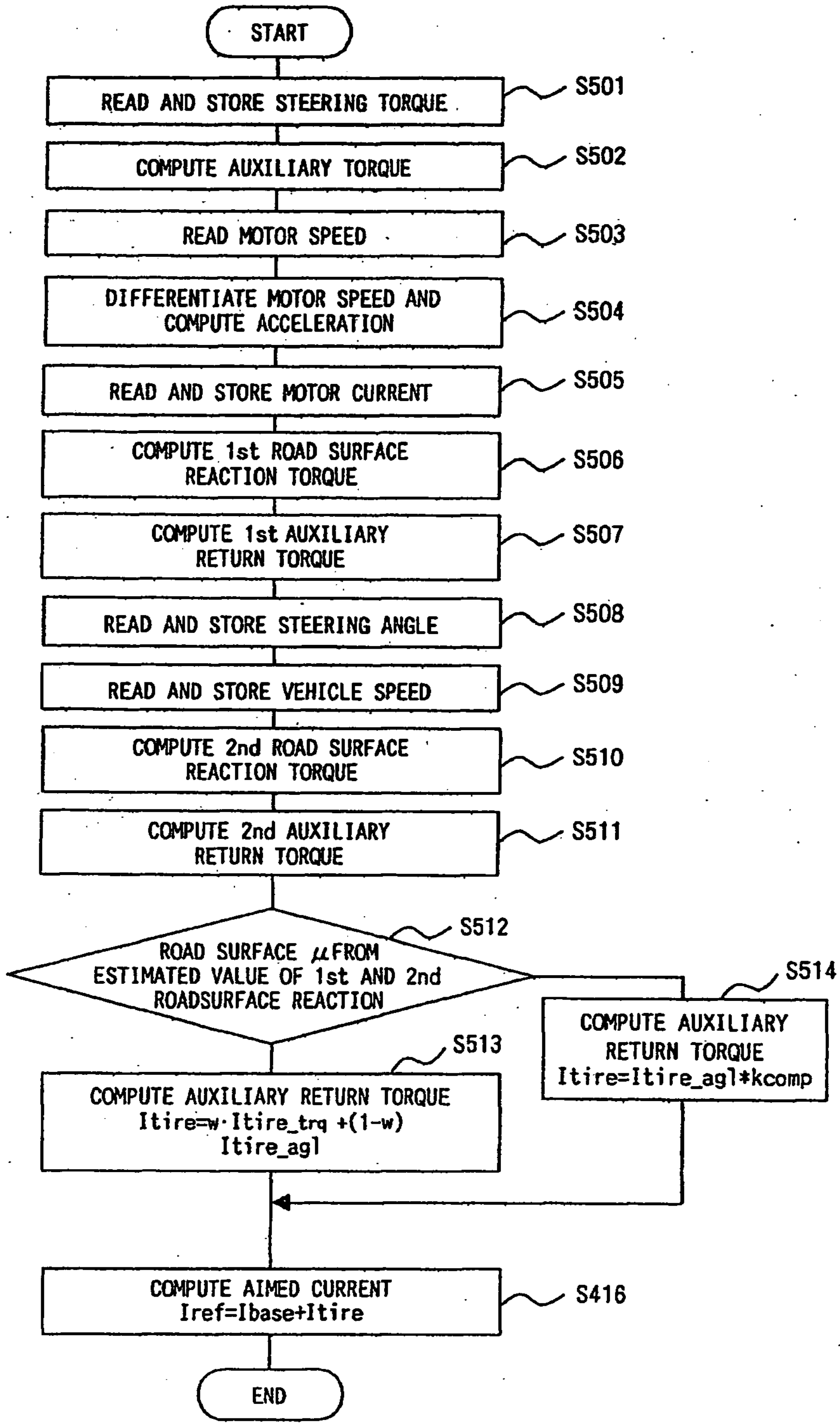
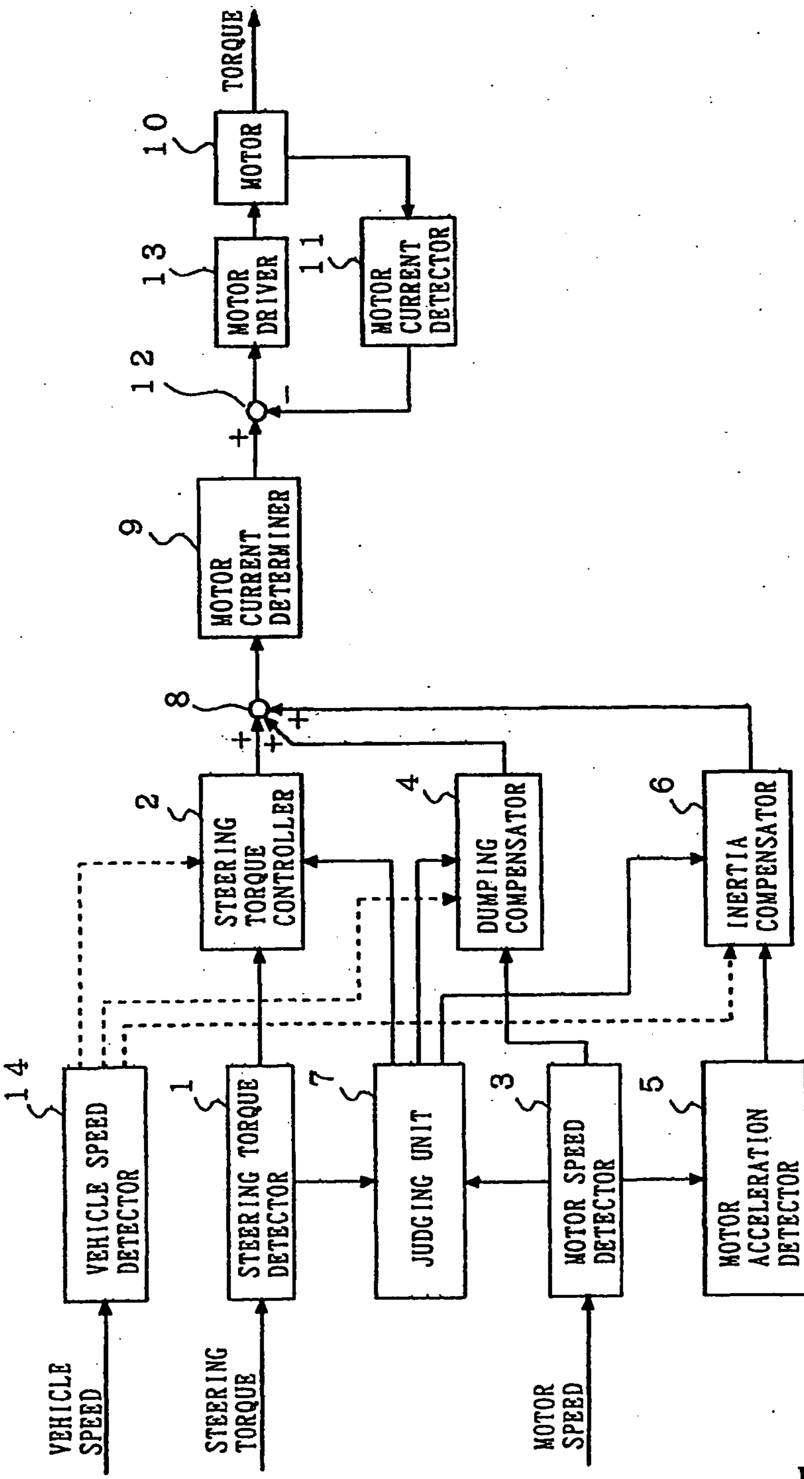

START
READ AND STORE STEERING TORQUE
S501
COMPUTE AUXILIARY TORQUE
S502
READ MOTOR SPEED
S503
DIFFERENTIATE MOTOR SPEED AND COMPUTE ACCELERATION
S504
READ AND STORE MOTOR CURRENT
S505
COMPUTE 1st ROAD SURFACE REACTION TORQUE
S506
COMPUTE 1st AUXILIARY RETURN TORQUE
S507
READ AND STORE STEERING ANGLE
S508
READ AND STORE VEHICLE SPEED
S509
COMPUTE 2nd ROAD SURFACE REACTION TORQUE
S510
COMPUTE 2nd AUXILIARY RETURN TORQUE
S511
ROAD SURFACE μ FROM ESTIMATED VALUE OF 1st AND 2nd ROADSURFACE REACTION
S512
S514
COMPUTE AUXILIARY RETURN TORQUE Itire=Itire_agl*kcomp
S513
COMPUTE AUXILIARY RETURN TORQUE Itire=w·Itire_trq +(1-w) Itire_agl
COMPUTE AIMED CURRENT Iref=Ibase+Itire
S416
END

Fig. 13



PRIOR ART

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 10 3535

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X Y	EP 0 860 347 A (KOYO SEIKO CO) 26 August 1998 (1998-08-26) * column 7, line 32 - column 14, line 33; figures *	1-3,6,8 5,7	B62D5/04 B62D6/00
Y	US 5 944 137 A (MOSER MARTIN ET AL) 31 August 1999 (1999-08-31) * claim 1; figure 2 *	5,7	
E	EP 1 077 171 A (MITSUBISHI ELECTRIC CORP) 21 February 2001 (2001-02-21) * abstract; figures 1,2 *	1,5,7,8	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)

B62D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	3 July 2001	Wiberg, S

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 01 10 3535

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

03-07-2001

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0860347 A	26-08-1998	JP 10230861 A	02-09-1998
		DE 19806458 A	20-08-1998
		US 6082482 A	04-07-2000
US 5944137 A	31-08-1999	DE 19634728 C	02-04-1998
		FR 2752810 A	06-03-1998
		GB 2316377 A,B	25-02-1998
		IT RM970518 A	24-11-1997
		JP 3079141 B	21-08-2000
		JP 10114275 A	06-05-1998
EP 1077171 A	21-02-2001	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82